How well do high resolution models reproduce tropical convection?

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HOW WELL DO HIGH RESOLUTION MODELS REPRESENT TROPICAL CONVECTION?

Kevin Pearson, Richard Allan

ESSC, University of Reading, UK

Robin Hogan, Grenville Lister

Department of Meteorology, University of Reading, UK

Abstract

Cascade is a multi-institution project studying the temporal and spatial organization of tropical convective systems. While cloud resolving numerical models can reproduce the observed diurnal cycle of such systems they are sensitive to the chosen resolution. As part of this effort, we are comparing results from the Met. Office Unified Model to data from the Global Earth Radiation Budget satellite instrument over the African Monsoon Interdisciplinary Analyses region of North Africa. We use a variety of mathematical techniques to study the outgoing radiation and the evolution of properties such as the cloud size distribution. The effectiveness of various model resolutions is tested with a view to determining the optimum balance between resolution and the need to reproduce the observations.

BACKGROUND

We are studying the formation and development of tropical convective storms over Africa as part of the CASCADE project. This partnership involves groups at the Universities of Reading, Leeds and East Anglia and the Met Office. The overall project will study the formation, development and interaction of storms with the global circulation using a mixture of idealised and case studies. These will involve running high resolution simulations with the Met Office Unified Model (UM).

We are testing the models initially by comparing the Outgoing Longwave Radiation (OLR) produced by the UM run at 12km and 4km resolutions to that measured by the Global Earth Radiation Budget (GERB) instrument on the first Meteosat Second Generation Satellite (Meteosat 8). The study region is centred over West Africa (5S-30N,25W-25E) from 2006 July 26 to 2006 August 7. The model is driven at the boundaries by ECMWF analysis fields. As a consequence, the model is not running in a “forecast” mode and the comparison process must utilize indirect statistical methods. This enables us to test the internal representation of the physical processes by the model while maintaining the same overall synoptic picture. Examples of the 12km model and GERB OLR data are plotted in Figure 1.

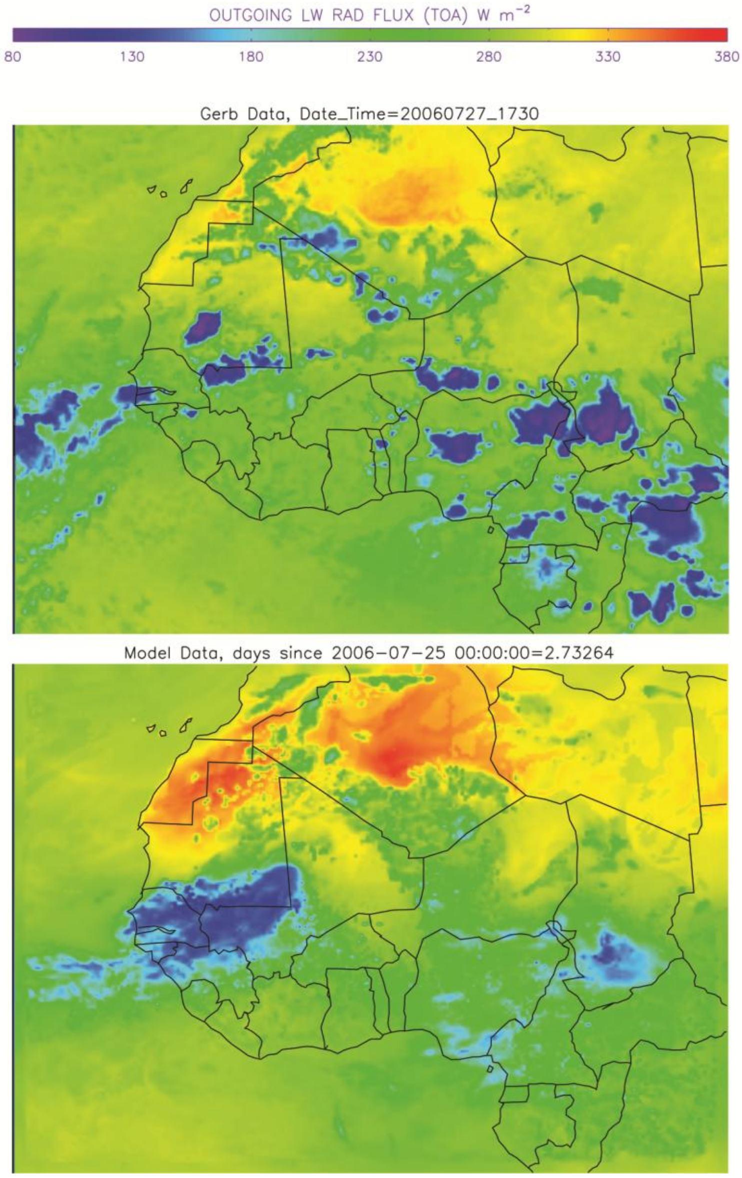

Figure 1: **GERB observed (upper panel) and Unified Model simulated (lower panel) outgoing longwave radiation fields for the same nominal time. The obvious differences between the two panels result from the model being driven only by analysis fields at the boundaries.**

SCALE-TIME RELATIONSHIP

Cloud pixels in the datasets are identified on the basis of a threshold flux level. The distribution of the storm sizes can then be used to compare the model and observations to each other and also to published results (eg. Mapes and Houze 1993, Cahalan and Joseph 1989). The greyscale level in figure 2 represents the logarithmic difference between the number of systems of a particular size and the time-averaged number at that size. The values are plotted as a function of system size and time folded onto a period of a single day.

Yang and Slingo (2001) used CLAUS data to show that the diurnal cycle of storms over Africa peaks too early in the UM compared to reality. These new results show additionally how large systems reach a maximum later in the day (20:00) than smaller systems (18:00) compatible with the paradigm of small thunderstorms forming, growing and merging. The 12km model data reaches a maximum consistently early (13:00) across all lengthscales whereas the 4km model shows much better agreement at medium to large lengthscales. At small scales, the 4km model peaks in the early morning as the large systems “shatter” into many small cloud clusters.

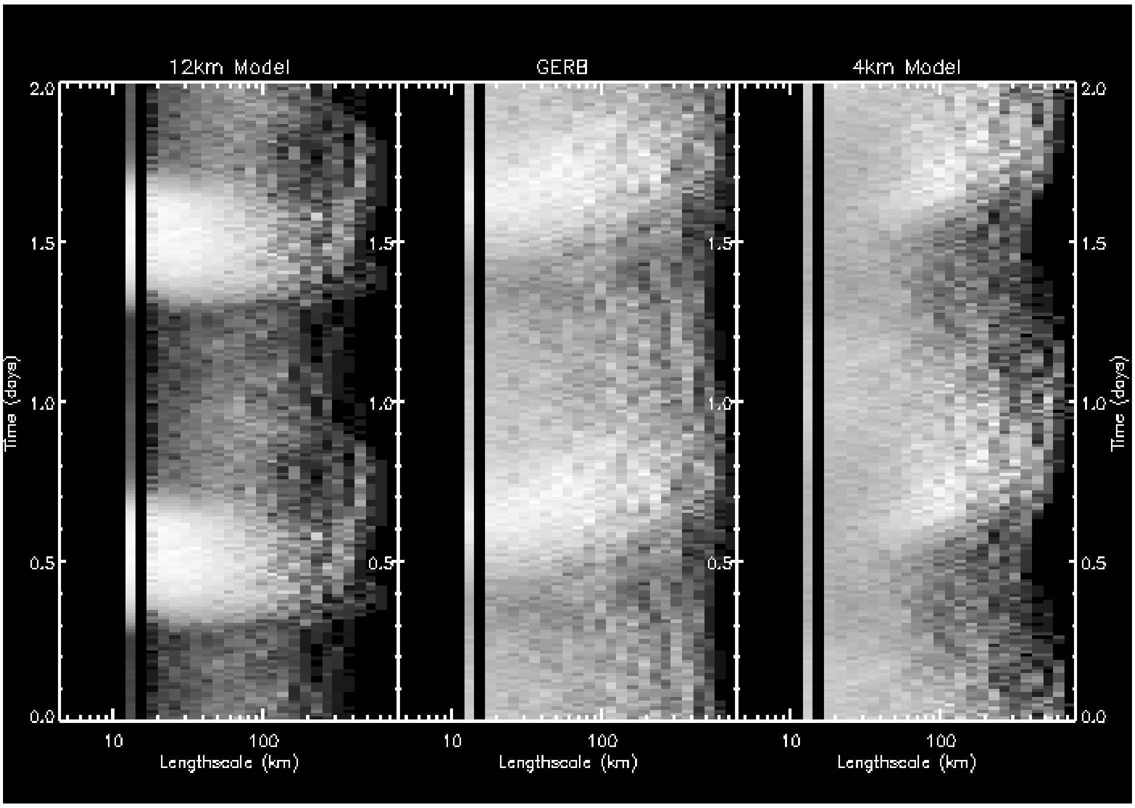

***Figure 2*: A comparison of the excess number of storms at each lengthscale for the observed GERB data and two model resolutions. The 4km resolution model shows much better agreement at moderate to large sizes.**

FLUX DISTRIBUTIONS

Figure 3 shows a histogram of the number of pixels against OLR at a particular snapshot in time. The clearsky OLR gives an indication of the region of the distribution populated by cloudy pixels.

While the major features in the distribution are common to both models and observations, the behaviour towards the lowest flux levels corresponding to cold clouds do differ. The 12km model does not produce pixels that reach the extreme of the observed distribution and over-produces warmer cloud pixels. However, the 4km model overlies the observed cloudy pixels remarkably well. The offset between the GERB and model “desert” fluxes probably results from the effects of dust that are not included in the models (Haywood et al. 2005).

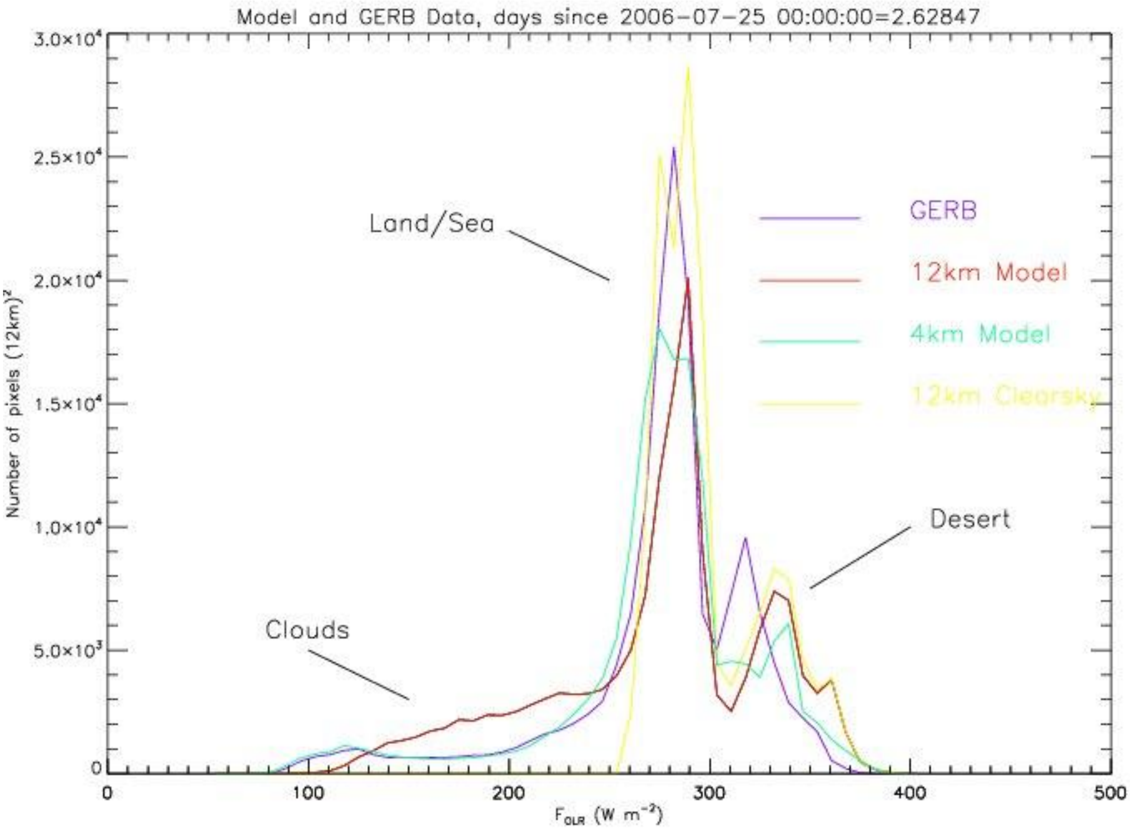

Figure 3: **A comparison of the pixel flux distributions for the observed GERB data and 2 model resolutions. Also plotted is the clearsky OLR values from the 12km model which gives a guide as to the regime dominated by cloudy pixels.**

FUTURE WORK

We plan to carry out simulations with improved model packages at 12km, 4km and 1km resolution over the same domain. These will enable us to test how the increased resolution improves the representation of the tropical convection. In particular, we intend to run without convective parametrization at the highest resolution to assess its impact on the results and to propose model improvements. We will also apply the tracking techniques of Futyan and Del Genio (2007) to follow the development of individual systems and study their properties.

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